

1 **THIN FILM CIRCUIT INTEGRATING THICK FILM**
2 **RESISTORS THEREON AND METHOD OF FABRICATING THE**
3 **SAME**

4 **BACKGROUND OF THE INVENTION**

5 1. Field of the Invention

6 The present invention is related to a thin film circuit integrating thick
7 film resistors thereon and a method of fabricating the same, in particular to a
8 method for fabricating a hybrid circuit board with integrated thick film resistors
9 on high density printed circuit boards by a combination of screen printing and
10 copper plating.

11 2. Description of Related Arts

12 For printed circuit boards, the current trend is towards high density circuit
13 layouts and planarization of components. It has always been a challenge for
14 circuit board manufacturers to produce high density circuit boards with high
15 efficiency.

16 A large percentage of components used on hybrid circuit boards are
17 resistors and capacitors. These passive components are conventionally coupled
18 onto printed circuit boards with surface mounting technology (SMT), which are
19 often referred to as SMD resistors and capacitors. However, the main
20 disadvantage of using SMD devices is their high profile. When these SMD
21 devices are coupled onto the circuit boards, the SMD devices tend to stand out
22 from the surface of circuit boards. Therefore, these SMD devices cannot be used
23 in present day compact electronic products due to the space requirements.
24 Furthermore, the surface mounting technology requires the creation of contact

1 pads at predetermined positions on the circuit boards before the resistors and
2 capacitors are mounted, which will increase the process time in the fabrication of
3 printed circuit boards and affect the production efficiency. Therefore, SMD
4 resistors and capacitors are gradually being replaced by thick film resistors and
5 capacitors in the planarization of semiconductor devices.

6 SUMMARY OF THE INVENTION

7 The main object of the present invention is to provide a method of
8 fabricating thin film circuits integrated with thick film resistors. The use of thick
9 film resistors to replace SMD resistors allows for the fabrication of integrated
10 thin film circuits, which is able to increase the productivity of printed circuit
11 boards and the yield rate of finished product.

12 To this end, the instrumentalities of the present invention involve a two-
13 phase process to produce the thin film circuits integrated with thick film resistor
14 components.

15 The first phase for producing thick film resistor components comprises the
16 acts of:

17 printing conductive electrodes for thick film resistors, wherein pairs of
18 electrodes are formed at predetermined positions on the surface of an insulating
19 substrate, which will act as the end terminals of thick film resistors;

20 printing a resistive coating for thick film resistors, wherein a thick layer of
21 resistive material is selectively placed in between pairs of electrodes for forming
22 thick film resistors; and

23 printing a passivation layer, wherein the layer of dielectric is formed over
24 the thick film resistors.

1 After finishing the formation of thick film resistor components on the
2 insulating substrate, the second phase can be started. The second phase calls for
3 the formation of a thin film circuit portion, comprising the acts of:

4 forming titanium and copper layers, wherein a titanium layer is first formed
5 over the substrate and then a copper layer is formed thereon, by the sputtering
6 technique, as the thick film resistors are already planted on the substrate;

7 attaching a dry film over the copper layer;

8 exposing and developing, wherein a photomask representing the circuit
9 pattern is first placed over the dry film for exposure under ultraviolet rays, and
10 then the dry film over the covered portion is etched away to expose the copper
11 layer underneath;

12 electroplating the thin film circuit portion for interconnections, wherein the
13 circuit portion undergoes an electroplating process to raise the circuit to an
14 appropriate height; and

15 removing remnants of dry film by lithographic etching, wherein excessive
16 amounts of dry film, copper and titanium materials have to be removed over the
17 substrate to create an integrated thin film circuit incorporating thick film
18 resistors.

19 Since the thick film resistors are formed on the insulating substrate by
20 screen printing technique, and the thin film circuit is formed by sputtering and
21 copper plating, the integrated printed circuit board is fully planar, and the circuit
22 layout for the circuit board can be more orderly and logical than the conventional
23 methods. Furthermore, in the present invention, there is no need to drill holes on
24 the substrate for electroplating lead wires, thus the process of fabricating printed

1 circuit boards can be automated to a greater extent than it would be otherwise
2 with conventional methods.

3 The features and structure of the present invention will be more clearly
4 understood when taken in conjunction with the accompanying drawings.

5 BRIEF DESCRIPTION OF THE DRAWINGS

6 Fig. 1 is a flow chart for the present invention.

7 Fig. 2 is plan view of the formation of conductive electrodes on a substrate.

8 Fig. 3 is a plan view of the formation of resistive coating in between
9 electrode pairs to form thick film resistors.

10 Fig. 4 is a plan view of the formation of a passivation layer over the thick
11 film resistors.

12 Figs. 5A-5F represent the fabrication process for thin film circuits.

13 Fig. 6 is a plan view of a thin film circuit incorporating thick film resistors.

14 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

15 The fabrication of a thin film circuit integrating thick film resistor
16 components thereon, in accordance with the present invention, involves a two-
17 phase process. The first phase calls for the formation of thick film resistors over
18 an insulating substrate (1), and the second phase is to produce a thin film circuit
19 on the substrate (1) with the thick film resistor components in existence.

20 The process flow for the fabrication of a thin film circuit is shown in Fig. 1,
21 where the first phase for forming thick film resistors includes printing conductive
22 electrodes (101); high temperature sintering (102); printing a resistive coating for
23 the thick film resistors (103); high temperature sintering (104); printing a
24 passivation layer with a dielectric material (105); high temperature sintering

1 (106); and cleaning and drying the thick film resistors (107). After the thick film
2 resistors are formed, the second phase process calls for the formation of a thin
3 film circuit, which includes forming a titanium layer and a copper layer (201);
4 printing a dry film (202); exposing and developing (203), electroplating circuit
5 interconnections (201); etching away remnants of the dry film and excessive
6 metal materials (205).

7 The detailed process of the first phase as shown in Figs. 1, 2 for forming
8 thick film resistors is described below.

9 The printing of pairs of conductive electrodes (11) on an insulating substrate
10 (1) is targeted at predetermined positions where resistors are to be placed, and
11 these electrodes (11) will become the end terminals of the resistors, and the
12 thickness of the conductive coating is about $25 \pm 5 \mu\text{m}$.

13 The high temperature sintering is used to set the electrodes (11) in place,
14 using a temperature of 850°C for 50 min.

15 The printing of a layer of resistive coating (12) for thick film resistors, as
16 shown in Fig. 2, is targeted at locations between the electrode pairs (11), where
17 the resistance of the material selected and the thickness of the coating have a
18 direct bearing on the resistance value of the resistors. Another factor affecting the
19 resistance value of thick film resistors (12) is the distance between two electrodes
20 (11). For example, if the shape of the resistive coating (12) between two
21 electrodes (11) of the thick film resistor layer (12) is changed from a rectangular
22 block to a continuous winding section, the effective length of the resistive
23 coating (12) is increased considerably; hence the resistance value between this
24 continuous winding section can be increased correspondingly.

1 The following step of high temperature sintering is used to set the resistive
2 coating (12) in place, using a temperature of 850 °C for 50 min.

3 The printing of a passivation layer (13), as shown in Fig. 4, is performed
4 over the thick film resistors (12), and the thickness of the layer is about $18 \pm$
5 $3 \mu\text{m}$. Since the resistance can also be affected by changes in ambient temperature
6 and humidity, this is a low temperature process to form the dielectric layer over
7 the resistors to protect them against outside influences such as changes in
8 ambient temperature and humidity.

9 The following step of high temperature sintering is used to set the
10 passivation layer (13) in place over the thick film resistors (12), the same as that
11 used for the conductive electrodes (11).

12 The final step of cleaning and drying finishes up the formation of thick film
13 resistors over the substrate (1).

14 After forming the thick film resistor, the second phase for forming thin film
15 circuit can be started, as shown in Fig. 5A.

16 The first step is the formation of titanium and copper layers (201) over the
17 insulating substrate (1), wherein a titanium layer (21) is formed over the substrate
18 (1) by a sputtering process, with thick film resistors in existence, and then a
19 copper layer (22) is formed over the titanium layer (21), where the thickness of
20 the titanium layer (21) is about $1000\text{--}1250 \mu\text{m}$, and the copper layer (22) is about
21 $4000 \mu\text{m} \pm 10\%$.

22 The next step calls for the attaching of a dry film (23), as shown in Fig. 5B,
23 over the copper layer (22), where the dry film (23) is a polymer based resin that
24 will become reactive when exposed to ultraviolet rays.

1 Before exposing the circuit portion, a photomask (24) is first aligned and
2 placed over the circuit portion of the dry film (23) to form a photo resist layer
3 against subsequent lithographic etching, and then the dry film (23) is placed
4 under ultraviolet rays to cause polymerization. Since the circuit portion is
5 shielded by the photomask (24), the ultraviolet rays cannot penetrate the
6 photomask (24). The portion of the dry film (23) covering the circuit portion will
7 not be subjected to ultraviolet rays and no polymerization results, as shown in Fig.
8 5c.

9 The developing process (203) involves the use of a developing solution to
10 remove the portion of the dry film (23) without polymerization (that is, the
11 locations for setting the circuit pattern), using an etching process to expose, the
12 copper layer (22) representing the circuit pattern, so that the circuits can be
13 produced with planar effect and fine shape.

14 The next step calls for the electroplating the exposed circuit pattern, as
15 shown in Fig. 5D to produce desired interconnections, forming a plated copper
16 circuit (25) having an appropriate thickness.

17 The last step of removing remnants of dry film (23) over the substrate (1) as
18 shown in Fig. 5E is to use lithographic etching or other means. Also, excess
19 amounts of the copper layer (22) and the titanium layer (21) other than those
20 required for the plated copper circuit (25) are removed to produce the hybrid thin
21 film circuit.

22 As shown in Fig. 6, each thick film resistor over the substrate (1) can be
23 connected to the corresponding position on the thin film circuit through the
24 electrodes (11).

1 It should be emphasized that even though in the present example the thick
2 film resistor components and thin film circuit are all formed on the same surface
3 over a substrate (1), the same process can be applied to create a double sided
4 circuit board integrating the thick film resistor components and the thin film
5 circuit portion on both sides of the substrate (1).

6 From the above description, the fabrication of the thin film circuit with the
7 integrated thick film resistors does not need the drilling of holes on the substrate
8 nor the electroplating of the lead wires. Therefore, the fabrication process of
9 printed circuit boards can be automated to a greater extent than that with the
10 conventional SMT technique.

11 The foregoing description of the preferred embodiments of the present
12 invention is intended to be illustrative only and, under no circumstances, should
13 the scope of the present invention be so restricted.